Mr Yelloly

A

DESCRIPTION

OF THE

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ORRERY:

WHEREIN THE
Structure and ſeveral Parts
OF THAT
CURIOUS MA[illegible]
Are fully Ex[illegible].

WITH
The Method of Ordering the In-
ſtrument, and [illegible] and Purpoſes which
it is adapted [illegible]

By T[illegible]

NEWCASTLE: Printed by W. CUTHBERT.

BRITISH MUSEUM

A
DESCRIPTION
OF THE
ORRERY.

THERE have been various mechanical Devices made uſe of to [illegible] and explain the Diſcoveries of Aſtronomers, and to account [illegible] the viſible and ap[illegible] [illegible] Univerſe: [illegible] of hi[illegible] has generally been occaſion[illegible] preference [illegible] all the reſt. Whence it has happen'd that the worſt Inſtruments have been commended and the beſt degraded [illegible] none are ſo complete and perfect, but that they contain many Defects and Errors, which are ſufficient Ground for Cavils and Objections; neither have any Inſtruments been ſo weakly contriv'd, but that ſome good Purpoſe has been tolerably anſwer'd, which has afforded Reaſon of Recommendation and Encomium. Amongſt them all, thoſe are the beſt Inſtruments which are the moſt comprehenſive and leaſt defective; and thoſe are the worſt, which contribute to the feweſt Ends and are moſt imperfect. It is ſufficient here, to obſerve, that the ORRERY has been more uni-

verſally

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verſally well received than any other Machine; and tho' the moſt chargeable, there have nevertheleſs been a greater Number made and ſold of thoſe Inſtruments, than of all others put together.

It takes its Name from the late Earl of *Orrery*, who, if not the ſole Inventor of it, was at leaſt the firſt Encourager of its being made. Orreries are made of various Sizes, and to ſeveral Degrees of Perfection: Some only exhibit the Appearances of the Sun, Earth, and Moon; others have the two inferior Planets added; others contain all the primary Planets with the Sun and Moon, but want the Satellites of *Jupiter* and *Saturn*; but the moſt compleat Machine of this Kind is made to repreſent the whole Syſtem of the Planets in ſo juſt and intelligible a Manner, that by it, Perſons who have not had Opportunities of ſtudying Aſtronomy, may, at a very ſmall Expence of Time and Application, attain a competent Knowledge of the Situations, Magnitudes, Motions, and ſeveral Appearances of the Sun, Earth, Moon, and all the other known Planets primary and ſecondary.

The Sizes of Orreries are from [illegible] to four Foot in Diameter. That which I ſhall [illegible] particularly deſcribe, is a compleat Orrery of [illegible]. It ſtands upon a hexagonal Frame [illegible] Mahogony, two Foot and four Inches high, [illegible] betwixt four and five Foot over. [illegible] ſix Feet, each reſting [illegible] by [illegible] of which, the [illegible] thirty Stone, is eaſily turned [illegible] or removed from one Place to another. The [illegible] of the Orrery I ſhall deſcribe in the following [illegible], *viz.*

I. *Of the* STRUCTURE *of the* ORRERY.

1. An Ebony Cheſt or Box, [illegible] Foot high, and four Foot in Diameter; the Circumference of which is compoſed of 12 perpendicular Planes or upright Sides, forming an equal Number of Angles or Corners, ſupported upon the Frame by Braſs Feet, neatly carved and gilt: Upon the Sides are curiouſly painted the 12 Signs of the Zodiac, encompaſſed with Radiences of Gold, on an Azure Skie.

2. This Cheſt contains a ſurprizing Number of Braſs Wheels and Movements, accurately adapted to anſwer the Purpoſes of the Orrery, hereafter mentioned.

3. The Top of the Cheſt is cover'd by ſeven round moveable Plates of Braſs, all colour'd Blue, except the firſt, which is a ſmall circular gilt Plate, with the Face of the Sun engraven upon it; this is placed in the Center or Middle of the Machine, and round it, lie horizontally the other ſix Plates: They are thin broad Rings, one larger than another, and made to move or ſlide one without another; all of them being Circles, concentric with the ſmall Plate firſt mentioned.

4. Into one of the Sides (mention'd in Art. 1.) there is occaſionally inſerted a Winch or Handle, which taking hold of an Axle within the Cheſt, by being turned about ſets all the Wheels and Movements to work, with which the aforeſaid thin Plates properly communicating, they are carried horizontally round, with ſuch proportionable Velocities, as the Nature of the Inſtrument requires. For,

5. Into the Movements within the Cheſt, are fixed Spindles or ſmall Wire [illegible], which riſe the Height of about three Inches thro' [illegible] made for that Purpoſe in the aforeſaid thin Plates; upon the Tops of which Stems, little round Bodies or Balls are put, to repreſent the Planets, *viz.*

6. Upon the Top of a Stem [illegible] firſt mention'd round Plate, near [illegible] placed a Braſs Ball guilt, to repreſent the Sun.

7. Upon the Stem which riſes through the annular Plate next the Sun, is put a ſmall Braſs Ball, which repreſents the Planet *Mercury*.

8. In like Manner, thro' the next Plate, riſes the Stem which bears the Repreſentative of *Venus*.

9. Next to *Venus*, being the 3d in Place from the Sun, is the Earth, which is repreſented by an Ivory Ball, ſupported upon its proper Stem ariſing above the 4th Plate.

10. More diſtant from the Sun and next to the Earth, *Mars* is deſcribed by a ſmall Braſs Ball guilt, borne upon the Stem of the 5th Plate.

11. Further ſtill, from the Sun and thro' the 6th Plate, appears the Supporter of *Jupiter*, which is repreſented by a large gilt Ball. And,

12. The moſt diſtant from the Sun of all the primary Planets is *Saturn*, which is borne upon the Stem or Spindle riſing above the 7th and outtermoſt Plate. In this Manner, the Sun and all the ſix primary Planets, are placed in the Orrery, truly repreſenting the Order of Nature in the Solar Syſtem.

13. Into each Corner upon the Surface of the Ebony Cheſt, is ſcrew'd a ſmall Braſs Pillar, ſo that 12 of theſe (ſtanding round the Machine, without the Plate of *Saturn*) ſupport a broad Braſs Ring, at the ſame Height that the Sun and Earth ſtand in the Orrery. The Surface of this Ring repreſents the Plane of the Ecliptic, which is divided into 12 equal Parts correſponding with the 12 Signs painted upon the Side of the Box below. Alſo upon this Ring, ſeveral Circles are drawn; the innermoſt of which, next the above Diviſions, is divided into 12 Times 30 equal Parts, which are the Number of Degrees in every Sign. The next Circle is divided into as many equal Parts as there are Days in the Year; and the outermoſt Circle (contiguous to the laſt mentioned) is cut into 12 unequal Parts, expreſſing the 12 Months of the Year, ea[illegible]mprehending its proper Number of Days on the [illegible] adjoining; and all exactly adapted to the Diviſions of the Signs; ſo that looking upon a[illegible] Day of the Month, we have the Sign and Degr[illegible] he S[illegible]en in, correſponding with that Diviſion[illegible]trary, having the Sun's Place in the Ec[illegible] gi[illegible]and a[illegible]ing to it, the Month and Day [illegible]hat Time.

14. Upon the large Plate, where the Earth appears (as mentioned in Art. 8.) are placed two ſmall, circular, concentric Plates, moveable about the Spindle which ſupports the terreſtrial Ball, in the ſame Manner as the larger Plates before deſcribed, are moveable about that which ſupports the Sun. Through the innermoſt of theſe Planes or Plates, riſes a Stem which ſupports the Repreſentative of the Moon; and into the outermoſt Plate are fixed two Props or Supporters, diametrically oppoſite to one another, bearing an oblique or ſloping Braſs Ring; one half of which is lower and the other half higher than the Earth, above the Surface of the Cheſt; the two Props being of the ſame Height and bearing the oppoſite Parts of the Ring, which reſt imme-

diately upon them, even with the Braſs Ecliptic, deſcribed in the Art. above. The inner Edge of this ſloping Ring very nearly touches the Moon, and repreſents the Plane of the Moon's Orbit or Path round the Earth. The two oppoſite Parts of it which lie upon the Props are called the Moon's Nodes; and as the Moon in paſſing by the Edge of this Ring round the Earth, riſes from the lower Part of it to one of the Nodes, that is called the Aſcending Node or Dragon's Head; and having paſs'd the upper Part of her Orbit, ſhe falls to the other Node; this is called the Deſcending Node, or Dragon's Tail: Alſo, as the Moon is ſometimes above and ſometimes below the Plane of the Ecliptic, the Diſtance which ſhe is from it, at any Time, is termed her Latitude; the greateſt Diſtance (which is when ſhe is at the higheſt and loweſt Points, called the Moon's Limits) is five Degrees and eighteen Minutes; and this, with all the other intermediate Degrees of Latitude, are engrav'd upon the Ring, beginning at the Nodes and number'd both Ways from them. Likewiſe upon the ſame Ring, without the Diviſions of Latitude, a Circle is deſcribed and divided into 360 Degrees, or four Times 90, beginning, as thoſe of Latitude, at the Nodes, and in like Manner, number'd both Ways from them; by which the Diſtance of the Moon in her Orbit from each Node, is found at any Time by Inſpection.

15. Upon that Part of the Earth's annular Plate, which is oppoſite to the Earth and Moon, is fix'd a Braſs Circle reſembling the Face [illegible] a Clock, but leſs; having two Hands, or Pointers, like the Hour and Minute Pointers. The Limb of this Circle bears two engrav'd Circles, the outermoſt of which is divided into 24 equal Parts, anſwering to the Hours of the natural Day, to which is adapted the firſt and longer Hand or Pointer. The innermoſt Circle is mark'd with 60 equal Diviſions, to which the ſecond and ſhorter Hand points. In uſing the Machine, while the laſt mentioned Hand goes once round, the firſt goes 60 Times round; and therefore, theſe two Hands keep an Account or Regiſter of any Number of Days and Hours paſt, between one Time and another, not exceeding 60 Days. But to make this circular Plate ſtill more uſeful, there are two Apertures or Holes cut in the Face of it, thro

which, two Parts of another Braſs Plate appear; which Plate is a moveable Circle, placed under the former. Upon this Braſs Circle, the Signs of the Ecliptic and Degrees of the Signs, the Months and Days of the Month, and the Seaſons, Spring, Summer, Autumn, and Winter, are engrav'd; ſo that the Plate being turn'd round, and the Diviſions coming ſucceſſively to the Apertures, the Seaſon, Month, Day of the Month, and Sun's Place in the Ecliptic, anſwering to any Poſition of the Planets, are thereby eaſily diſcover'd, in a Manner reſembling that whereby the Day of the Month and Moon's Age, are exhibited upon the Faces of Clocks. Let us hereafter, for Diſtinction's Sake, call theſe two Plates and Hands, *The Dial*.

16. There are four ſmall Cylindrical Braſs Sockets or Caſes, ſo made as to be put one within another, and to be turned round, without one another. Theſe Sockets being of unequal Lengths, their Tops ſtand at different Heights, to which ſmall bent Wires or Stems are fixed, upon whoſe Extremities or Points four ſmall Braſs Balls are put; and theſe are the Repreſentatives of the Satellites or Moons of *Jupiter*: For the Sockets being ſlip'd over the Spindle which carries the Planet *Jupiter* in the Orrery, that Spindle becomes an Axle to them, and the four Satellites being borne up to the Height of *Jupiter* at their proportionable Diſtances; by turning the Sockets about, they are carried round that primary Planet [illegible] the Moon is carried round the Earth.

17. By the ſame Contrivance that the Satellites of *Jupiter* are ſupported and made to revolve about his Body, the five Satellites or Moons of *Saturn* are placed and turned round their primary Planet: And alſo upon the Spindle or Stem which ſupports *Saturn*, another ſmall Socket is placed, ſo as not to touch or depend upon the Sockets which belong to the Satellites. This, by two ſhort bended Wires, ſupports a ſmall oblique or ſloping Ring, which encompaſſes the Body of *Saturn* at a proper Diſtance from it, between the Planet and the neareſt Satellite. Thus *Saturn*'s Ring, and all the ten ſecondary Planets or Moons, are placed in the Orrery, in the ſame Order that they are in Nature, viz. one belonging to the Earth, four to *Jupiter*, and five with a

Ring to *Saturn*. *Mercury*, *Venus*, and *Mars*, are not yet certainly known to have any Satellites; tho' *Caſſini*, looking through a 34 Foot Teleſcope in the Years 1672 and 1686, thought he ſaw a Moon belonging to *Venus*; which Diſcovery has lately been further confirmed by the Obſervations of Signior *Bianchini*: However, as Aſtronomers are not fully agreed about it, the Orrery has not yet given it a Place.

18. The Sun and all the Planets, ſix primary and ten ſecondary, being diſpoſed of in this Manner, and encompaſs'd by the Braſs Ecliptic, explain'd in Art. 13. a large Armillary Hemiſphere (reſting upon the ſaid Ecliptic) covers the whole Machine and compleats the Orrery. This Armillary Hemiſphere conſiſts of ſeveral Braſs Circles, neatly poliſh'd and gilt, viz. 1. An Equinoctial, accurately divided and number'd; 2. the Tropic of Cancer, letter'd; 3. the Arctic Circle, letter'd; 4. the Equinoctial Colure, divided and number'd; and, 5. the Solſtitial Colure, divided and number'd. The two laſt mention'd Circles ſtand at right Angles with or perpendicular to the three firſt, and alſo interſect, or cut one another, at right Angles in the Pole of the World.

II. *Of the* METHOD *of ordering the* ORRERY, *with its* USES *and* PURPOSES; *in which alſo ſeveral other Parts, Apparatus, and Things remarkable, not mention'd in the former Section, are explain'd.*

19. To give a general Idea of the Planetary Syſtem, I apprehend the eaſieſt Method is to advance to it by an Induction of Particulars, making our Approaches fair and ſoftly; and therefore, by removing all the Planets out of the Orrery, we ſhall only have one Ball or Globe left in it, which is the Repreſentative of the Sun, ſtanding upon his Spindle in the Center of the Machine. Now, by turning the Winch or Handle about, we do not find that the Sun is remov'd out of his Place; but we obſerve that his Orb turns round upon its Axis, which is made apparent by ſeveral Spots on its Surface.

20. Put the Terreſtrial Ball into its proper Place; then again turning the Handle, we obſerve the Earth rolls about its Axis with greater Speed than the Sun: and, to find how much ſwifter the Motion is, we are to

look upon the Dial, explain'd in Art. 15. and we ſhall ſee that one Turn of the Winch carries the Hour Hand or Index once round thro' all the 24 Hours, which is equal to one natural Day; and at the ſame time the Earth alſo compleats an entire Revolution upon its Axle; but the Sun, at the End of this Turn, has but advanced a ſmall Part of his Revolution; one Turn of the Handle more makes the Earth perform another diurnal Period; and the Sun has advanced as much again as he did at the firſt: And thus repeating the Turns of the Handle, we ſhall find at laſt, that when the Sun's Orb has finiſhed its Period, or is got quite round, the Earth will have made 25 Turns and about a Quarter more. For if, at the Beginning of this Obſervation, the Hour Index of the Dial was ſet to Twelve, and the other Index to the Beginning of the 60 diurnal Diviſions, we ſhall ſee, at the End of one Period of the Sun, that the Diurnal Index ſtands at 25 Days, and the Hour Index at ſix Hours; which very clearly illuſtrates ſo much of the Syſtem, viz. that the Earth turns round its Axis in 24 Hours, and the Sun in 25 Days and ſix Hours.

21. On each Side of the Handle there is a Stop or Pin, which may be drawn out or puſhed into the Cheſt. When the Stop on the Left Hand of the Winch is drawn out, the Movements which carry the Primary Planets about the Sun, are diſcharged from their Operation; and when it is puſhed in, the Axle of the Winch lays hold of the ſaid Movements, and turns the Primary Planets in their Orbits or Circles round the Sun. In like manner, the Stop upon the Right Hand of the Winch diſcharges, or ſets to work the Motions of the Satellites. Theſe Stops are of great Service to preſerve the Machine, and that the Motion of ſo many heavy Wheels and Parts may not clog the Performance, and wear the Inſtrument, when there is no occaſion for it.

22. The Left Hand Stop being puſhed in, and the Winch turned about, we obſerve not only the Earth and Sun to revolve as before, upon their reſpective Axles, but alſo the Earth moves round the Sun with ſuch Velocity or Swiftneſs, as that at the End of 365 Turns and one fourth of the Handle and Hour Index, the Earth is ſeen to have compleated a Revolution or circular Path round

the Sun. This Path is called the Earth's Orbit, and it lies in or coincides with the Plane of the Ecliptic. During this Performance the following Particulars are fully illuſtrated, viz. the apparent Motion of the Sun, and the real Motion of the Earth thro' all the 12 Signs of the Zodiac or Ecliptic; and alſo the relative Motions of thoſe two Orbs upon their Axles, with reſpect to one another. To make this moſt plain, bring about the Earth ſo that a ſtreight Line or Wire being laid over the Sun and Earth both Ways to the Braſs Ecliptic, that End which is next the Sun may point out the Beginning of *Aries*, and then the other End, next the Earth, will point at the Beginning of *Libra*. In this Poſition the Sun appears entering into *Aries*, and the Earth, at the oppoſite Point of the Ecliptic, is entering into *Libra*, which happens about the 9th or 10th of *March*; to which Time let the under Plate of the Dial and the Indexes be adjuſted. Then turning the Winch, we ſhall ſee that End of the Wire next the Sun begin to move and proceed thro' the ſeveral Degrees of *Aries* towards *Taurus*, and the other End at the ſame time approaching with equal Speed through *Libra* towards *Scorpio*; the laſt pointing out and ſhowing the real Motion of the Earth in the Ecliptic, and the other the apparent Motion of the Sun thro' the 12 Signs: during which, a faithful Account of the Months, Days and Hours, paſſed and paſſing, are exhibited by the Dial: Where it may be obſerved, that the Sun's apparent and Earth's real Motion thro' the Ecliptic is nearly one Degree every Day, and a whole Sign, or 30 Degrees, in 30 Days and 10 Hours.

23. Next to the Earth put the Ball which repreſents *Venus* in its proper Place nearer the Sun; then turn the Handle and we may obſerve this Planet rolling upon its Axis, and at the ſame time carried forwards in its Orbit about the Sun: and, by looking upon the Dial, we ſhall find that *Venus* compleats a Revolution round the Sun, by 224 Turns and one fourth of the Handle, or in 224 Days and 16 Hours; and alſo turns about on her Axis in 24 Days, according to the late Diſcovery of Signior *Bianchini*. To illuſtrate other Appearances of *Venus*, there are two ſmall Rods or Wire Indexes, one of which is laid over the Earth and *Venus*, and the

other over the Sun and *Venus*. The firſt of thoſe Rods points out the Place of the Ecliptic which *Venus* appears to be in, as beheld from the Earth, which is called its *Geocentric Place*; and the other ſhows where it appears in the Ecliptic, as beheld from the Sun, which is called its *Heliocentric Place*. Then turning the Handle about, the Geocentric and Heliocentric Motions of *Venus* are clearly illuſtrated by thoſe two Rods, which are faſten'd to the Sun and Planets by ſmall ſliding Pins: and alſo that Rod which lies over the Earth and *Venus*, plainly ſhews how that Planet appears to us ſometimes to go forwards, ſometimes backwards, and at other times to ſtand ſtill amongſt the fix'd Stars; tho' really it always proceeds regularly from Weſt to Eaſt in its Path round the Sun. Next, to explain the *Elongations* of *Venus*, there is a double Index made of two Steel Wires, opening like a Pair of Compaſſes, with a graduated Braſs Arch fixed to the Extremity of one of them. The Center of this Index being placed over the Center of the Earth by a Pin, and one Leg ſtretched over the Sun and the other over *Venus*, and kept there by two moveable Pins, then, the Handle being turned about, *Venus* will be moved forwards in its Orbit, and thereby the Legs of the Index will be opened or cloſed, ſhewing the Decreaſe or Increaſe of the Planet's Elongation, by an intercepted Part of the aforeſaid Arch, which will be ſeen never to exceed 48 Degrees.

24. The Planet *Mercury* being put into its proper Place between the Sun and *Venus*, all its Appearances are ſhown in the ſame Manner as thoſe of *Venus*, *viz.* its Period, or Revolution about the Sun, by 88 Turns of the Handle nearly; its Geocentric and Heliocentric Places; its appearing ſtationary, progreſſive, and retrograde in its Courſe thro' the Ecliptic; and its Elongations, which at greateſt is 28 Degrees.

N. B. As this Planet has not yet been diſcover'd to revolve about its Axis, the Orrery therefore does not give it that Motion.

25. After this Manner the Appearances of the two inferior Planets being illuſtrated, in the ſame Way the Phœnomena of the three ſuperior Primaries are explain'd, by putting on, 1ſt, *Mars*, which revolves upon

its Axis in 24 Hours and 40 Minutes, and about the Sun in 687 Days nearly; then *Jupiter*, which turns on its Axis in 9 Hours and 56 Minutes, and finiſhes its Period round the Sun by 4332 Turns and a Half of the Handle, or in 11 Years, 314 Days, and 12 Hours; and laſtly, *Saturn*, the moſt remote from the Sun of all the known Primary Planets. Its Rotation upon its Axis is not diſcover'd, but it performs its Period round the Sun by 10,759 Turns of the Handle nearly, or in 29 Years, 167 Days, and 22 Hours. The Revolutions and Periods of *Mars*, *Jupiter*, and *Saturn*, being thus illuſtrated, their Geocentric and Heliocentric Places, with their apparent Progreſſions, Stations, and Retrogradations are explained by the ſame Wire Rods, and in the ſame Manner as thoſe of *Venus* and *Mercury*.

26. The Motions of the Sun and ſix Primary Planets being diſpatch'd, the Balls made uſe of in the Illuſtration are laid aſide: And now, to fix in the Minds of the Spectators a juſt Idea of the proportional Magnitudes of the Planets, a new Set of Orbs are placed in the Orrery, whoſe Sizes are proportion'd to one another as the Magnitudes of the Planets are, according to the Obſervations and Diſcoveries of the beſt Aſtronomers. In this Illuſtration a proportional Sun cannot be made uſe of: For, to an Earth of three Tenths of an Inch in Diameter, the Sun would be above two Foot in Diameter, and conſequently fill more than the Orbit or Path of *Jupiter* in the Machine, and thereby exclude all the Planets except *Saturn* from the Orrery; and, if the Planets ſhould be proportion'd to a Sun of three Inches Diameter, (which is as much as the Inſtrument will allow of) then the Earth's Diameter would not be one Third of a Tenth of an Inch, ſcarce viſible to the Eye, and *Mercury* and *Mars* would be ſtill far leſs: So that a Set of ſuch Planets, inſtead of helping the Matter, would be entirely uſeleſs. The Sun therefore, which is in proportion to the Planets made uſe of on this Occaſion, is not a Ball placed in the Orrery, but is repreſented by the Path or Orbit of *Jupiter*, ſhewn in the Machine by a gilded Circle of two Foot Diameter.

The Situations, Motions, and Magnitudes of the Primary Planets being thus illuſtrated in general, before we proceed to the Phænomena of the Satellites or Secondaries,

daries, we ſhall explain ſome other Appearances, which particularly belong to the Earth, and depend entirely upon its Poſition and Motion.

27. There is a ſmall Wire ſupported by two Props between the Sun and Earth, which points directly from the Center of one to the Center of the other. This Wire repreſents a ſolar Ray, or Stream of Light coming from the Sun to the Earth, and therefore always ſhews the Place which lies directly under the Sun, or which the Sun at any time is vertical to.

28. There is an Ivory Ball made to repreſent the Earth, with ſeveral Meridians, the Equator, Ecliptic, Tropics, and Polar Circles drawn upon it; as alſo a Sketch of the Countries and Oceans, in the ſame Manner that they are deſcribed upon common Globes. This Ball is put into the Orrery, with its Axis inclined to the Plane of the Ecliptic in an Angle of 66 Degrees and one Half.

29. There is a Wire-Index ſupported upon two Props in that Part of the Earth's Orbit which is exactly oppoſite to the Earth; ſo that it points from the Center of the Sun to the large Braſs Ecliptic; and thereby ſhews the Sun's Place at all times, as beheld from the Earth, and alſo the correſpondent Month and Day of the Month.

30. The Sun, the Earth, the Solar Ray and the laſt mentioned Index, being all put into their proper Places, we bring about the Earth's Plate till we ſee the Sun's Place to be in the Beginning of Cancer on the 10th Day of June; then obſerving the Solar Ray, we ſee it points to the Tropic of Cancer, drawn on the Earth, and the North Pole ſtanding towards the Sun; then puſhing in the Stop, which gives the Earth its annual Motion, we turn about the Handle, whereby the Earth is carried forward in its Orbit, and the Sun apparently proceeds thro' *Cancer* towards *Leo*, as before explain'd: At the ſame time the Solar Ray deſcribes the Ecliptic upon the Earth receding from the North towards the South; ſo that when the Earth has gone over a Quarter of its Orbit, and the Sun appears entering into *Libra* on the 11th of *September*, the Solar Ray points exactly at the *Equator*; and, turning the Winch ſtill about, the Solar Ray purſues the Courſe of the Ecliptic as drawn on

the Earth towards the South, till the South Pole is turned towards the Sun, and the Index, which ſhews the Sun's Place, comes to the 10th of *December*, when the Earth has perform'd one half of its Revolution, and then the Solar Ray has gained the Tropic of *Capricorn*, which is the Sun's Limit towards the South: From thence the Solar Ray reverts along the Ecliptic towards the North, and comes on the 9th of *March*, when the Sun enters into *Aries*, to point again at the *Equator*, the Earth having performed three fourths of its Revolution; the Winch being ſtill kept turning, the Solar Ray ſtill approaches the North, and at the End of 365 Days and 6 Hours, the Earth having compleated its Period, the Sun again ſtands at the Beginning of *Cancer*, and the Solar Ray points at the Tropic which is the Limit of the Sun's Acceſs to the North. Thus the apparent Courſe of the Sun thro' the Ecliptic, and the various Poſitions which it ſtands in at different Seaſons, to the Northern and Southern Parts of the World, are fully explain'd.

N.B. In this laſt Illuſtration the diurnal Motion of the Earth is prevented, in order to make the Effects of the annual more plain and viſible.

31. There is a ſmall Braſs Arch in the Form of a Creſcent, wanting about 47 Degrees of an entire Circle. This Arch is ſupported upon two Props at the End of a Wire which ſuſpends it vertically; ſo that it hangs over and encompaſſes the upper Part of the Earth perpendicularly, or at right Angles to the Solar Ray. This Arch therefore divides the Globe of the Earth into two equal Parts or Hemiſpheres, thereby defining and marking out that Hemiſphere which at any time is turned towards the Sun, and ſeparating it from the other, which is turned or hid from the Sun; and as this Arch thus divides the enlighten'd from the dark Part of the Earth, it is called a Solar Horizon, and has *Day* engraved upon that Side which faces the Sun, and *Night* upon the other. It has alſo W. E. mark'd upon it, to ſhew the Weſt and Eaſt Points.

32. The Earth, with the Solar Horizon, ſtanding at the firſt Degree of *Cancer* as before, the Stop is drawn out which diſcharges the Earth from its annual Revolution, and a ſmall Wheel put on the Spindle that

ſupports the Earth, by which the diurnal Motion is reſtor'd. In this Poſition the Things to be obſerv'd are: that the North Pole is turned towards the Sun, and all that Part of the Globe, within the Arctic Circle, lies in the enlighten'd Hemiſphere, or Day; the South Pole and Antarctic Circles being totally turn'd from the Sun into the darken'd Hemiſphere or Night; and all the reſt of the Earth is divided into two equal Shares of Day and Night, by the Solar Horizon. Then turning the Handle, we obſerve, that all Places which lie between one Polar Circle and the other are carried from Weſt to Eaſt, and appear and diſappear alternately upon the light and dark Sides; *i. e.* every particular Spot within either of the Temperate or Torrid Zones, by one Turn of the Handle, will be made firſt to appear to the Sun under the Weſtern Edge of the Solar Horizon, (the Sun at the ſame time riſing or appearing to it in the Eaſt); from whence paſſing forwards thro' the englightned Hemiſphere, it will diſappear under the Eaſtern Edge of the Solar Horizon, (the Sun then ſetting in the Weſt); thence, by keeping the Handle going, it will paſs thro' the darken'd Hemiſphere or Night, and appear again in the Weſt as before. But this Rotation of the Earth does not occaſion any Place in the Northern Frigid Zone to diſappear, becauſe the whole Arctic Circle lies in the enlighten'd Hemiſphere, or on that ſide of the Solar Horizon next the Sun: Neither does any Place in the Southern Frigid Zone appear in the Day, the whole Antarctic Circle being turned from the Sun beyond the Solar Horizon. It is further to be obſerv'd, that, during this Operation, all Places under the Equinoctial or Equator continue in the Day and Night, equal Times; but thoſe to the North of the Equator, have longer Days than Nights: and the more ſo the further North they are ſituated, till approaching to the Arctic Circle it becomes all Day, and no Night. On the contrary, thoſe Places to the South of the Equator have ſhorter Days than Nights; which Inequality ſtill increaſes to the South, till we gain the Antarctic Circle, and from thence to the Pole all is Night and no Day.

33. All Things being in the ſame Condition as before, we may accurately obſerve the Lengths of Day and Night in any Place, by bringing the Place under the

ern Edge of the Solar Horizon, and putting the Hour-Index upon the Dial-Plate to XII. then turning the Handle till the ſaid Places come under the Eaſtern Edge of the Solar Horizon; there ſtopping, we ſhall ſee how many Hours the Index has paſſed over, which is the true Length of the Day in that Place; then putting the Index again to XII. and turning the Handle till the Place having paſſed thro' the darken'd Hemiſphere returns under the Weſtern Edge of the Solar Horizon, the Hours paſſed over will ſhew the Length of the Night. Thus we ſhall find, that at *Newcaſtle*, between the Sun riſing and ſetting is 16 Hours and a half, and between the Sun ſetting and riſing only 7 Hours and a half.

34. Turn the Earth's Plate about till the Earth comes to the Beginning of *Aries*, and the Sun to the firſt Degree of *Libra*, on *September* 11th: Then, every thing being order'd as before, we ſhall obſerve the two Poles come under the Solar Horizon and one half of each Polar Circle in the Day, and the other in the Night; as alſo the Tropics and all the Parallels of Latitude, equally divided by the Solar Horizon: ſo that, turning the Handle about, all Places upon the Globe will be ſhown to enjoy equal Portions of Day and Night, except the Poles, which remaining unmoved on the Limits between Light and Darkneſs, cannot properly be ſaid to have or to want either Night or Day.

35. Bring the Earth's Plate about till the Sun comes to the Beginning of *Capricorn*, and the Earth to *Cancer* on the 10th of *December*; then will the North Pole and the Arctic Circle be turned into the Night, and the Antarctic Pole and Circle, into the Day: So that every thing will happen exactly the contrary of what was obſerv'd in Art. 32 and 33, the Days now being longeſt and Nights ſhorteſt to the Southern Parts of the World, and the Nights longeſt and Days ſhorteſt to the Inhabitants of the North; at *Newcaſtle*, between the Sun riſing and ſetting, 7 Hours and a half, and between ſetting and riſing, 16 Hours and a half.

36. The Earth being removed to the Beginning of *Libra*, and the Sun to *Aries*, on the 9th of *March*, Day and Night will again be ſhown equal all the World over, as in Art. 34.

Thus are the four cardinal Points of the Year fully explain'd, *viz.* the two Solſtices and two Equinoxes, which define the Beginning of the Spring, Summer, Autumn, and Winter Quarters. And further,

37. All things remaining as in the laſt Article, the Earth in its due Poſition, and every Particular as it ought to be, on the 9th of *March*, at the Commencement of the Spring Quarter, puſh in the Left Hand Stop, and turn the Handle: Then will the Earth perform both its Rotation upon its Axis and alſo its annual Revolution; by which the Sun will apparently (or relatively) be carried thro' the Ecliptic, according to the Order of the Signs, and in the Compaſs of 365 Days and 6 Hours by the Dial, the whole uninterrupted Progreſs of the Year thro' the four Seaſons, and the Sun's Courſe thro' the Zodiac, will be compleated, and clearly illuſtrated, by the Solar Ray and Horizon, after the ſame manner as the four cardinal Points in the laſt five Articles.

38. To explain other particular Phœnomena depending upon the Poſition and Motion of the Earth, and to make the various Appearances of the Sun in the Courſe of the Year ſtill more plain, there is another Ball to repreſent the Earth, whoſe Diameter is three Inches, with a compleat Map of all the known Terraqueous Globe, neatly delineated and colour'd upon its Surface. To this Globe there is fitted a *ſilver'd Horizon*, mark'd with Circles and Diviſions, like that belonging to a common Globe; to which is fix'd a *graduated Meridian*, with a *Pin* at 90 Degrees Diſtance from the *Horizon*: and (as the *Meridian* and *Horizon* are eaſily moveable upon the Globe) this *Pin* being brought to any Place, and the *Meridian* put into its due North and South Poſition, the *Horizon* will be truly adjuſted to that Place. The Uſes are as follow:

39. The *Pin* being brought to the *North Pole*, the *Horizon* will exactly coincide with the *Equator*; which Condition of the Globe is called a *Parallel Sphere*, all Parallels of Latitude being parallel to the Horizon. Put the Globe thus order'd into the Orrery, and ſet it in due Poſition at the firſt Degree of *Libra*, (the former *Ball* and *Solar Horizon* being taken away) then will the *Solar Ray* point directly to the Edge of the *ſilver'd Horizon*; and the Handle being gently turned round,

the Earth will roll upon its Axis, the *Solar Ray* tracing along the *Horizon*, without deviating in the leaſt to the North or to the South: Which ſhews that, on the 9th of *March*, the Sun does not appear to the Terreſtrial Poles, either to riſe or to ſet, but paſſes round thro' all Points of the Compaſs, the Plane of the *Horizon* ſtill biſecting the Sun's Disk. But, giving the Earth its annual Motion, and continuing to turn the Handle, the *Solar Ray* (and conſequently the Appearance of the Sun) will in a few Days be obſerved to have left the Horizon, and to come into the Northern Hemiſphere, ſtill approaching nearer and nearer to the North Pole for three Months together, *viz.* from the 9th of *March* to the 10th of *June*; in which time the Sun, in his apparent diurnal Motions, has deſcrib'd a Spiral, or rather Helix, whoſe Baſe is the Equator; and Vertex, the Tropic of *Cancer*: at which Point (being the *Summer Solſtice*) the Sun will appear to the North Pole for the Space of many Days together, not to be ſenſibly leſs than 23 Degrees and a half high, (which is equal to the Meridian Altitude of the Sun at *Newcaſtle* about the 12th of *October* and 7th of *February*). From thence the Solar Appearance (explain'd by the *Solar Ray*) gradually winds its Helix back again, and arrives at the *Horizon* and Autumnal Equinox on the 11th of *September*; the Earth then entering into *Aries* and the Sun into *Libra*; the North Pole having had continual Day, and the South Pole having been hid in the Night for half a Year. But now, the Operation being carried on, the *Solar Ray* gains the Southern Hemiſphere, making ſix Months Day to the South Pole, and Night as long to the North, after the ſame manner as above explain'd, arriving on the 10th of *December* at the *Winter Solſtice*, and thence returning to the *Vernal Equinox* on the 9th of *March*, which in this Caſe coincides with the *Horizon* as before.

40. The *Pin* being removed from the North Pole, and placed any where in the Equator, the ſilver'd Horizon will encompaſs the Earth ſo as to paſs thro' both Poles. The Globe in this Poſition is called a *right Sphere*; the Equinoctial, and all the Parallels of Latitude, ſtanding at right Angles, or perpendicular to the *Horizon*. Then, turning the Handle till the Earth

compleats a Year, or one Revolution about the Sun, we ſhall obſerve all the Solar Appearances as they happen to the Inhabitants of the Line or Equator, to be clearly illuſtrated, *viz.* 1. That the Sun riſes at Six and ſets at Six o'Clock all the Year long; and conſequently, that the Days and Nights are perpetually equal. 2. That on the 9th of *March* and 11th of *September*, the Sun at Noon is in the Zenith, *i. e.* vertical to, or exactly over the Heads of the Inhabitants. 3. That one half of the Year (between *March* and *September*) the Sun is every Day at Noon full North, and the other half (between *September* and *March*) it bears full South off the Inhabitants; the Meridian Altitude being never leſs than 66 Degrees and a half, which occaſions the exceſſive Heat and Intemperance of the *Torrid Zone.*

41. The *Pin* being remov'd out of the Equator, and ſet upon any Place betwixt the *Line* and the *Poles*, the *Horizon* will not then paſs thro' either of the *Poles*, nor coincide with the Equator, but cut it obliquely; one half of the Equator ſtanding in a ſloping Poſition above, and the other below the Horizon. The Globe, thus ordered, is call'd an *Oblique Sphere*; of which there are as many Varieties as Places between the Equator and either Pole. But one Example will ſerve to illuſtrate all the reſt: for whatever Appearances happen to one Place, the ſame, as to kind, happen to every other Place; one differing from another only in Degree as their Latitudes differ. We therefore bring the Pin to *Newcaſtle*, and rectify the Poſition of the Meridian: Then will the ſilver'd Horizon juſtly repreſent the Horizon of *Newcaſtle*; and in one Revolution of the Earth round the Sun, we ſhall have all the Solar Appearances thro' the four Seaſons clearly exhibited in the Orrery, as they really are in Nature, *viz.* the Earth ſtanding at the firſt Degree of *Libra*, the Sun then entering into *Aries*. Turn the Meridian to the Solar Ray, and put the Hour Index to XII. then ſhall we have the Earth ſtanding in its true Poſition with reſpect to the Sun, as it does on the 9th of *March*, when it is Noon at *Newcaſtle*. Turn the Handle gently, and when the Solar Ray comes to the Weſtern Edge of the Horizon, the Hour Index will point at VI. which ſhews the Time of the Sun's ſetting. *Newcaſtle* then turning into the

Night, continues in Darkneſs till the Hour-Index, having paſt over twelve Hours, comes again to VI. at which time the Solar Ray gains the Eaſtern Edge of the Horizon, thereby defining the Time of the Sun's riſing; and ſix Hours afterwards the Solar Ray recovers the Meridian, and the Index points at XII. thereby evidently demonſtrating the Equality of Day and Night, when the Sun is in the Equinoctial: And it may alſo be obſerved, that the Sun then riſes due Eaſt and ſets due Weſt, the Solar Ray pointing all the Day long exactly at the Equator drawn upon the Earth. But turning the Handle a little faſter, to haſten the annual Revolution, we ſhall quickly obſerve, that the Solar Ray declines from the Equator towards the North, and every Day at Noon riſes higher upon the Graduations of the Meridian than it did the preceding Day, continually approaching to *Newcaſtle*, the Days at the ſame time growing longer and longer, and the Sun riſing and ſetting more and more towards the North, till the 10th of *June*, when the Earth arrives at the firſt Degree of *Capricorn*, and the Sun appears in the Tropic of *Cancer*, riſing at three Quarters paſt III. in the Morning, on the N. E. Point of the Compaſs; and coming at Noon to 58 Degrees and a half Altitude on the Meridian, and from thence deſcending to the N. W. Point on the Horizon, where the Sun ſets at a Quarter paſt paſt VIII. in the Evening, and after continuing ſeven Hours and a half in the Nether Hemiſphere, appears riſing again in the N. E. as before. From the 10th of *June* to the 11th of *September*, the Sun recedes to the South, and the Days gradually decreaſe till the autumnal Equinox, when Day and Night become again equal. From thence, during the three following Months, the Sun continues to decline towards the South Pole, and the Days to decreaſe till the 10th of *December*, when the Sun enters the Tropic of *Capricorn*, riſing on the S. E. Point of the Compaſs at a Quarter paſt VIII. in the Morning; at Noon coming only to the Altitude of 11 Degrees and a half, and ſetting a Quarter before IV. in the Evening at the S. W. Point upon the Horizon; after which the Sun continues in the Nether Hemiſphere ſixteen Hours and a half, (thereby ſhewing the Length of the Night) and then appears again in the S. E.

as before. From the 10th of *December* the Sun returns towards the North, and the Days continually increaſe in Length till the vernal Equinox on the 9th of *March*, when all Things are reſtored into the ſame Order as at the Beginning of this Article.

Thus all the Varieties of the Seaſons; the Time of Sun riſing and ſetting, and at what Point of the Compaſs; as alſo the Meridian, Altitude, and Declination for every Day of the Year; and to what Place the Sun is at any time vertical; are fully exemplified and illuſtrated by this Three-inch Globe and its Apparatus of a Solar Ray, ſilver'd Horizon, and graduated Meridian.

42. To explain what is meant by a Solar Day and a Sydereal Day, and to demonſtrate their Difference, take off the Globe with its ſilver'd Horizon, and put on again the Ivory Ball mention'd Art. 28. which bring in due Poſition to the firſt Degree of *Capricorn*, and the Meridian of *Newcaſtle* to the Solar Ray, the North Pole will then ſtand directly towards the Sun, and the Plane of the ſaid Meridian will paſs thro' the Center of the Sun. Now, the Earth ſtanding diſcharg'd from its annual Motion, by every turn of the Handle it will be made to roll once round, and as often the Meridian of *Newcaſtle* will return exactly to the Point of the Solar Ray; in which caſe the Solar and Sydereal Day do not differ: But let us puſh in the Left Hand Stop, which gives the Earth its annual Motion; then, by one turn of the Handle, the Earth will not only make one Rotation upon its Axis, but alſo be carried a little forwards in its annual Path or Orbit: by which Means (the Earth's Axis always maintaining a Poſition parallel to what it was at firſt) the North Pole will be removed a little towards the Eaſt of the Sun, and alſo the Meridian of *Newcaſtle*, tho' it has been turned entirely round, will fall a little ſhort of the Solar Ray; and the Handle muſt be turn'd ſomewhat more than once about, before it will be full Noon at *Newcaſtle*, and the Plane of the Meridian will paſs thro' the Center of the Sun. And hence ariſes the Diſtinction: for the Time between Noon and Noon conſtitutes a Solar Day, and the Time in which the Earth exactly performs one Rotation on its Axis is term'd a Sydereal Day; which, by this Operation,

tion, is ſhewn to be ſomewhat leſs than a Solar Day: but as the Difference is ſmall, being ſcarce four Minutes, therefore one turn of the Handle hardly makes it ſufficiently apparent in the Machine, but by a few turns more, it will be made very viſible: For as every Sydereal Day falls near four Minutes ſhort of the Solar, if we put the Hour Index to XII. when the Meridian of *Newcaſtle* comes to the Solar Ray, and turn the Handle fifteen times about, which will finiſh 15 Sydereal Days, we ſhall obſerve that only 14 Days and 23 Hours are paſſed over by the Dial, and an Hour more will be required to make it Noon at *Newcaſtle*. Thus the Solar Day is ſhewn to conſiſt of 24 Hours, and the Sydereal Day only of 23 Hours and 56 Minutes; ſo that the Sydereal Year falls ſhort of the Solar Year by one Day: And tho' at the Beginning, the Solar and Sydereal Noons coincide and perfectly agree, yet ſix Months afterwards it will be Sydereal Midnight when it is Solar Noon. And this is the Reaſon that the fixed Stars are obſerved to riſe, come to the Meridian, and ſet every Night more early than that preceding. For Example, the Pleiades, or ſeven Stars, are obſerv'd in the Beginning of *December* to come due South about Ten o'Clock at Night, and a Month afterwards, in the Beginning of *January*, they appear on the Meridian before Eight o'Clock in the Evening. And after this manner all the Conſtellations of the Heavens, the whole Aſſemblage of the fix'd Stars, are apparently, with reſpect to the Sun, carried round the Sky from the Eaſt to the Weſt.

43. Before we quit the Phœnomena particularly ariſing from the Motion and Poſition of the Earth, there is another Ivory Ball to be put into the Earth's Place, in ſuch manner as that its Axis and Poles may ſtand perpendicular to the Plane of the Braſs Ecliptic; which being done, the Solar Ray will continually point at the Equator of the ſaid Ball, and never deviate in the leaſt to the North or South, tho' by turning the Handle, the Ball is made to compleat a Revolution about the Sun: Which ſhews that the Earth, in this Poſition, would have the Days and Nights equal in every Part of the Globe all the Year long; and that the Variety of the

Seaſons is entirely owing to its Axis being inclined to the Plane of its Orbit.

Thus having illuſtrated the Phœnomena of the Primary Planets in general, and alſo what ariſes particularly from the Inclination of the Earth's Axis to the Plane of the Ecliptic, and from its Rotation and Revolution; our next Buſineſs is

III. *To explain the* PHOENOMENA *of the Secondary Planets, Satellites, or Moons.*

44. There is a ſmall Ivory Ball made to repreſent the Moon, whoſe Hemiſpheres or Sides are diſtinguiſh'd by the one being black and the other white. Put this Ball into its proper Place in the Orrery, ſo as to ſtand in a Line between the Earth and Sun, with its white Side turned towards the Earth; then put the Indexes to XII. unlock the annual Motion, and turn the Handle, and we ſhall obſerve the following Particulars clearly illuſtrated: 1. That the Moon moves in her Obbit from the Weſt to the Eaſt. 2. That ſhe always keeps the ſame (white) Side turned towards the Earth; and therefore it is that we never ſee any Side of the Moon but one, as the Maculæ or Spots upon her Surface evince. 3. That the Moon's Rotation upon her Axis is made in the ſame Time that ſhe takes to perform her Revolution in her Orbit round the Earth. 4. That the Period of the Moon about the Earth is effected and compleated in 27 Days and 8 Hours nearly; which Time is by Aſtronomers called a *Periodical Month.*

45. To explain the Synodical Month, and ſhew how it differs from the Periodical, reſtore the Earth's annual Motion, and then turn the Handle till the Dial ſhews 27 Days and 8 Hours to have paſſed; in which Time the Moon will have finiſh'd its Revolution or Periodical Month, as by the laſt Article: but the Earth at the ſame time having proceeded in its annual Path or Orbit above 27 Degrees of the Ecliptic, the Moon will not be got round into a direct Line between the Earth and Sun, but will require two Days and four Hours more to bring it again to its Conjunction with the Sun: Which ſhews that an entire Lunation, call'd a *Synodical Month*, conſiſts of 29 Days and a half; and that the Time betwixt one Syzygie or Change and another, is, by means

of the Earth's annual Motion, above two Days longer than it would be if the Earth ſtood ſtill.

N. B. The Periodical and Synodical Months are beſt diſtinguiſhed, and made moſt conſpicuous, if the diurnal Motion of the Earth is prevented, during the Explanation.

46. To exhibit the ſeveral Phaſes of the Moon there is another Ivory Ball, half black and half white, incloſed within a black Cap, which turns round, and alternately, either totally or partially covers both the white and black Sides: This Ball being put into the Moon's Place, in a Line between the Earth and Sun, as before, with the black Cap exactly covering the white Side, the whole Lunar Orb will be dark; ſhewing thereby its Diſappearance at the time of its *Conjunction* or *Change:* then turning the Handle, the Moon will be moved in its Path about the Earth, and proceeding from its Conjunction, the Cap will begin to roll off the white Side, and exhibit a ſmall part of it in the Form of an Arch or Creſcent, (as is ſeen in the New Moon) which will continually increaſe till near the End of the Seventh Day from the Change, when we ſhall ſee half of the light and half of the dark Hemiſpheres turned towards the Earth; which illuſtrates the Appearance of the Moon at the *Firſt Quarter:* From thence the light Side will continually ſhow itſelf more and more in a gibbous Form, till at the End of about fourteen Days, the full white Side will be got from under the Cap, and all the illumined Half of the Moon will be turn'd to the Earth, and the dark Side from it, the Earth then ſtanding in a Line between the Sun and Moon; which explains the *Oppoſition*, or *Full Moon:* Then again turning the Handle, the Cap will begin to hide the light Side, and the illumin'd Part will decreaſe in a gibbous Appearance till the *Laſt Quarter*; from whence the Moon reſumes her Horns, and wains in a Creſcent to another *Conjunction*, where ſhe is cover'd with Darkneſs as before.

47. Slide about the Earth's Plate till the Solar Index (explain'd Art. 29.) comes to the 10th of *December*, and ſet the Lunar Orb to the Poſition of New Moon; ſo that the Sun and Moon being in Conjunction, they will both be viewed from the Earth in or near the Tropic of *Capricorn.*

pricorn. Then turn the Handle, and the Moon will revolve about the Earth from the Weſt to the Eaſt, according to the Order of the Signs; and in the Courſe of a Synodical Month the following Particulars will be clearly illuſtrated: 1. That the Moon is every Night above three Quarters of an Hour later in coming to the Meridian than it was the Night before; 2. that continually, from the Change to the Full, the Moon approaches toward the North, as the Sun was ſhown to do in the latter part of Art. 30. going thro' as many Signs in about a Fortnight as the Sun apparently paſſes thro' in half a Year; 3. that the Moon comes to the Full, or Oppoſition, when ſhe is in or near the Tropic of *Cancer*; 4. that hence the Reaſon appears of the light Moon's long Continuance above the Horizon in the Winter, thereby moſt uſefully beſtowing her Rays upon the Earth, in that Seaſon of the Year when the Nights are longeſt, and the Evenings would be leſs chearful without it.

48. Obſervations like the laſt being made upon the Moon, with the Earth and Sun ſtanding in due Poſition at the Beginning of the other three Quarters of the Year, all the reſt of the Lunar Appearances, depending upon the Moon's Courſe thro' the Zodiac, are fully explain'd; in which alſo is clearly manifeſted, that the great Advantage and Benefit of Mankind has been remarkably deſign'd and wiſely provided for, by the Author of Nature, in giving the Earth this Satellite, or Secondary Planet: For, the full Moon being always in that Part of the Zodiac which is oppoſite to the Sun, her Light ſhines upon us the longeſt when the Sun makes his ſhorteſt Appearance, as was ſhown in the laſt Article; but in the Beginning of the Spring, when the Days are of a middle Length, and upon the Increaſe, the Time of the Full Moon's Appearance above the Horizon is much ſhortned, and her viſible nocturnal Arch ſtill continues to leſſen as ſhe paſſes Southward to or beyond the Tropic of *Capricorn*, where ſhe arrives about her laſt Quarter: Alſo, in the Height of our Summer, when the Days are longeſt, and we have little or no occaſion for the Moon's pale Light, then is ſhe (at and about the Full) * furtheſt removed from us, caſting her borrow'd

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* The Moon's Perigee and Apogee are not here conſider'd.

Rays copiouſly on the Southern Inhabitants, to whom it is then the Depth of Winter: But, at the Beginning of the Autumn Quarter, when the Sun arrives at the Equator in his Retreat from the North, and the Nights begin to lengthen apace, while yet our Harveſt is not ended, and the ripe Fruits of the Earth require the Attendance and Labour of Man to get them timely gather'd in, then again comes the light Moon to our Aſſiſtance and Relief; ſo that about the Time that the Sun croſſes the Equinoctial declining to the South, the Full Moon alſo croſſes the Equinoctial in her Acceſs to the North; and in our oblique Sphere for many Nights after the Full, the Moon ſtill riſes before the Crepuſculum or Twilight ends; which accounts for the Phœnomenon of what is uſually termed the *Harveſt Moon*, or, as ſometimes it is called, the *Hunter's Moon.*

49. In order to explain and illuſtrate the Phœnomena of Eclipſes, it is firſt to be underſtood, that the Sun is the only real Luminary in the Solar Syſtem; and that none, either of the Primary or Secondary Planets, emit Light, but they all are opaque or dark Bodies, each of them having that Hemiſphere or Side which is turned to the Sun illuminated by his Rays, and the other involved in a deep Shadow, which is projected into the etherial Regions in the Form of a Cone or Sugar Loaf; which Form ariſes from the luminous Body of the Sun being greater than any of the Planets: For if one of them were greater, or equal to the Sun in Magnitude, then its Shadow would be of infinite Length; but proportionably as they are leſs, and placed nearer or further off the vaſt Orb of the Sun, the Apices or Tops of their conical Shadows are at greater or leſs Diſtances from them. Thus the Shadow of *Mercury* reaches not ſo far beyond its Orb as that of *Venus* beyond hers, nor is the Shadow of *Venus* ſo long a Cone as that of the Earth; but the Shadow of the Earth is greater, and extends further into the Heavens than the Shadow of the Moon, *&c.*

50. When the Shadow of the Earth falls upon the Moon, it makes *an Eclipſe of the Moon*; and when the Shadow of the Moon falls upon the Earth, it makes *an Eclipſe of the Sun:* So that an Eclipſe of the Moon never happens but when the Earth's dark Body interpoſes between the Sun and Moon, *i. e.* at the Oppoſition, or

Full Moon; and an Eclipſe of the Sun never happens but when the Moon comes into a Line between the Earth and Sun, *i. e.* at the Conjunction or Change of the Moon.

N. B. The Reaſon why the Primary Planets never eclipſe one another, is, becauſe their Shadows are ſhorter, or terminate at leſs Diſtances from their Orbs than they are ſituated one from another.

51. If the Plane of the Moon's Orbit coincided with the Plane of the Ecliptic, there would be a total Eclipſe of the Moon every Full, and a central Eclipſe of the Sun every New Moon; but as the Path of the Moon round the Earth is oblique to the Path of the Earth round the Sun, ſo there are but two Points in the Moon's whole Courſe, called her Nodes, where ſhe comes exactly into the Plane of the Ecliptic; being every where beſides either above or below the ſaid Plane, which is the Reaſon that Eclipſes happen ſo rarely: For, except the Moon, at the Full or Change, is in or near one of her Nodes, there will be no Eclipſe; becauſe, when her Latitude or Diſtance from the Plane of the Ecliptic exceeds the Sum of the apparent Semidiameters of the Moon and Earth's Shadow, and ſhe comes at that Time to the Full, (which is moſt generally the Caſe) then, as the Axis of the Earth's Shadow always lies in the Plane of the Ecliptic, the Moon will be too far on one Side or other of it to ſuffer any Eclipſe; or, if the New Moon happens when her Latitude exceeds the Sum of the apparent Semidiameters of the Sun and Moon, the Moon's Shadow will fall on one Side or other of the Earth, ſo as not to touch it, and there will be no Eclipſe of the Sun.

52. The Apparatus of the Moon, explain'd in Art. 14. being duly applied to the Orrery, all that has been ſaid in the three laſt Articles will be clearly illuſtrated, and alſo the Preceſſion of the Moon's Nodes, ſo as to compleat her Cycle in nineteen Years.

53. *Jupiter*, with his four Satellites, and *Saturn*, with his five, being placed in the Orrery, the various *Motions*, *Periods*, *Tranſits*, and *Eclipſes* of thoſe Secondaries, are explained and illuſtrated after the ſame manner as the Phœnomena of the Moon: Alſo, by ſliding the Plate of *Saturn* about we ſhall obſerve the various Phaſes of his Ring, as beheld from the Earth, *viz.*

1. That tho' *Saturn's* Ring is abſolutely circular, yet, from its Poſition, it can never appear to a Spectator on the Earth, more than an Ellipſis or Oval, whoſe greateſt Diameter is double its leaſt; 2. that as the Poſition of the Ring maintains a Paralleliſm thro' the whole Revolution of *Saturn*, ſo it will ſeem to vary its Form perpetually, now growing broader, then again narrower, and ſometimes almoſt diſappearing, the Edge of it being turned to the Earth, and no more of it ſeen but the two extreme Parts, looking like ſmall Anſœ, or Handles, to the Orb of *Saturn*.

54. To give the Spectators a general Idea of the Motions of *Comets*, there is a ſtrong gilded Wire, the Ends of which are faſten'd by Screws into the Circles of the Armillary Sphere, (*vide* Art. 18.) from whence deſcending into the Orrery, it is bended round at a ſmall Diſtance from the Sun. This Wire repreſents the lower Part of the Trajectory, or Path of a Comet, and has a gilded Ball that ſlides eaſily upon it, which being let go from one of the Circles of the Armillary Sphere, will, by its own Gravity, deſcend along the Wire; thereby ſhowing the Motion of a Comet in its Orbit, and its coming to its Perihelion, or neareſt Approach to the Sun.

55. A particular Explanation being thus given of the various Phœnomena of the Sun and the Planets, primary and ſecondary, we next exhibit the whole Syſtem together, putting all the Eighteen Bodies into their proper Places, *viz.* the *Sun*, *Mercury*, *Venus*, the *Earth* with the *Moon*, *Mars*, *Jupiter* with his *Four Satellites*, and *Saturn* with his *Ring* and *Five Satellites*. Let the whole be adjuſted to any particular Time by an Ephemerides, and regulate the Dial to the ſaid Time; then, by turning the Handle, we ſhall have at one View the whole Operation of the Planetary Syſtem, and all the various Changes and Phœnomena therein, regularly carried on in the Orrery as they really are in Nature. But, to make this ſtill more conſpicuous and entertaining,

56. *Laſtly*, we have a Lantern, contrived for this Purpoſe, which we put into the Place of the Sun, and make the Room dark, ſo that no Light may appear but that which the Lantern gives thro' a Convex Glaſs; by means of which it more ſtrongly illuminates the Planets: Then turning the Handle, we ſhall have an ex-

act and beautiful Repreſentation of the whole Planetary Syſtem; and (without the Solar Ray, Horizon, and other Apparatus mention'd before) we ſhall behold moſt naturally exhibited, the Phœnomena of the Seaſons, the Increaſe, Decreaſe, and Lengths of Days and Nights round the Year, the various Phaſes of both Primary and Secondary Planets, and all the Eclipſes, Tranſits, and other Appearances and Changes, depending on the Illumination of the Sun, that have yet been diſcover'd by Aſtronomers.

FOR the further Satisfaction of the Reader, it has been thought proper to add the following Particulars, which contain a more exact Account of the Motions, Magnitudes, Diſtances, &c. of the Planets, than is poſſible to be expreſs'd in a Machine.

I. *Diſtances from the Sun in* Engliſh *Miles, ſuppoſing the Sun's Paralax* 10 *Seconds.*

Mercury, - -	32,000000	*Mars*, - -	125,000000
Venus, - -	59,000000	*Jupiter*, - -	426,000000
The *Earth*, -	82,000000	*Saturn*, - -	780,000000

II. *Periodical Times of their Revolutions round the Sun, in Days, Hours, &c.*

	Days	hours	min.		Days	hours	min.
Mercury, - -	87	23	16	*Mars*, - -	686	23	27
Venus, - - -	224	16	49	*Jupiter*, -	4332	12	20
The *Earth*,	365	6	9	*Saturn*, -	10759	6	36

III. *Rotations upon their Axes.*

	d.	h.	m.		d.	h.	m.
The *Sun*, - -	25	6	00	*Mars*, - - -	1	0	40
Mercury, - -	not known.			*Jupiter*, - -	0	9	56
Venus, - - -	24	8	00	*Saturn*, - -	not known		
The *Earth*, -	00	23	56				

IV. *The Velocities of the Planets may be computed from the Miles (that at a mean rate) they paſs over in an Hour,* viz.

Mercury, - - -	94000	*Mars*, - - - -	48000
Venus, - - - -	69000	*Jupiter*, - - -	26000
The *Earth*, - -	59000	*Saturn*, - - -	19000

V. *Dia-*

V. *Diameters in* Engliſh *Miles.*

Sun,	793,000	*Mars,*	004,800
Mercury,	002,600	*Jupiter,*	077,000
Venus,	007,900	*Saturn,*	067,000
The *Earth,*	007,935		

VI. *Proportional Solid Contents.*

The *Sun,*	1000000	*Mars,*	1 5th
Mercury,	1 27th	*Jupiter,*	899
Venus,	1	*Saturn,*	612
The *Earth,*	1		

VII. *Proportional Denſities.*

The *Sun,*	25	*Mars,*	not known
Mercury,	not known.	*Jupiter,*	19
Venus,	not known.	*Saturn,*	15
The *Earth,*	100		

VIII. *Proportional Quantities of Matter.*

The *Sun,*	227,500	The *Moon,*	1 40th
Mercury,	not known	*Mars,*	not known
Venus,	not known	*Jupiter,*	220
The *Earth,*	1	*Saturn,*	94

IX. *Proportional Degrees of Light and Heat.*

Bodies cloſe by the Sun, 45,000.

In *Mercury,*	6	In *Mars,*	1 10th
Venus,	2	*Jupiter,*	1 27th
The Earth,	1	*Saturn,*	1 30th

X. *Periodical Times of the Satellites.*

The Moon revolves round the Earth, and at the ſame time round its own Axis, in 27 Days, 7 Hours, 43 Minutes, at the Diſtance of 240,000 Miles from the Earth's Center; its Denſity to that of the Earth, as 123 to 100; its Diameter, 2175 Miles.

Jupiter's Satellites revolve round his Orb,

	D.	h.	m.	ſ.		D.	h.	m.	ſ.
1ſt, in	1	18	28	36	*3d,* in	7	3	59	40
2d,	3	13	18	52	*4th,*	16	18	5	6

Saturn's Satellites revolve round his Orb,

	D.	h.	m.	ſ.		D.	h.	m.	ſ.
1*ſt*, in	1	21	18	31	4*th*, in	15	22	41	11
2*d*,	2	17	41	27	5*th*,	74	7	53	57
3*d*,	4	13	47	16					

Diſtances of Jupiter's *Satellites in Semidiameters of* Jupiter.

1*ſt*,	5 & 2 thirds	3*d*,	14
2*d*,	9	4*th*,	25 & 1 third

Diſtances of Saturn's *Satellites in Semidiameters of* Saturn.

1*ſt*,	4 & 3 8ths	4*th*,	18
2*d*,	5 & 3 5ths	5*th*,	54
3*d*,	8		

E R R A T A.

In Page 11. Art. 23. Line 7. inſtead of one fourth, read *three fourths*; Page 17. Art. 33. l. 6. for Places come, read *Place comes*; Page 24. Art. 44. for Obbit, read *Orbit*.